CONDUCT, SCIENCE AND PUBLIC POLICY, SUSTAINABILITY

The Science behind Global Warming

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What Is Global Warming?

Global warming is an alarming phenomenon that is characterized by a drastic increase in the average global temperature in the Earth's atmosphere. Studies show that since 1950, the average Earth's temperature has risen at the fastest rate in recorded history. The current temperature rise of approximately 1°C is detrimental and encompasses extreme weather events, rising sea levels, melting ice sheets, shifting habitats, and epidemic risks. Note that global temperature records are an estimate across the entire surface of the planet. In fact, the average global temperature is a function of the amount of energy received from the Sun and then radiated by the Earth, which depends largely on the chemical composition of the atmosphere and the levels of heat-trapping greenhouse gases.

The current global temperature rise of 1°C may reach 2°C, putting people, wildlife, and nature at risk. A UN report released by the Intergovernmental Panel on Climate

Change (IPCC) warns that if authorities fail to keep global warming at 1.5°C above preindustrial era levels, drastic climate change effects will occur by 2040. In order to avert global warming, rapid solutions on the individual, national, and international levels are required – with science playing a crucial role in the process.

Is Global Warming Real?

Although the global significance of the climate changes happening right now is eminent, global warming has become a hot topic marked by skepticism and controversy. Interestingly, climate change denial that contradicts scientific evidence is a common phenomenon, with high prevalence across the US. In a 23-country survey conducted by the YouGov-Cambridge Globalism Project, Indonesia (18%), Saudi Arabia (16%), and the US (13%) revealed the highest percentage of manmade climate deniers.

In the US alone, 13% of respondents said global warming is real, but human activity is not responsible, while 5% denied global warming is happening. Demographics influence climate change denial, with white Americans over 55 years revealing high levels of denial. Political views and the media are also major factors shaping people's opinions; 52% of Republicans in the US, for instance, are more likely to ignore global warming. Interestingly, more than 56% of elected Republicans also deny the science behind global warming. We should note that President Trump was one of the main political figures fueling the climate-related conspiracies, claiming that global warming was a hoax fabricated by China and the UN 2015 Paris Climate Agreement a tactic to undermine the US economy.

Scientific Evidence for Global Warming

Despite all the controversy and political interests, the science behind global warming is clear: global warming is a fact. Satellite and laboratory data show that the trapping of carbon dioxide and other pollutants in the atmosphere causes the Earth to warm. With more than thousands of weather stations around the world, buoy-based measurements, and Antarctic research, scientists show that climate change in response to CO2 and aerosols is imminent. Additionally, ancient evidence found in tree rings, glacial ice, coral reefs, and sedimentary rocks shows that the current warming is 10 times faster than the average rate of ice-age-recovery warming. In fact, proxy-based temperature variations reveal that today's surface temperature changes are anomalous for the past 1,300-1,700 years (Mann et al., 2008). Scientific evidence shows that the Earth's climate is changing due to the greenhouse effect

and various manmade causes of pollution, resulting in landslides, flooding, and shifting of populations:

- **Global temperatures are increasing:** The average global temperature has increased with more than 0.9°C over the past century, with significantly higher rates over the last 35 years. In the US, in particular, the five warmest years on record took place in the last decade, with 2018 being the fourth warmest year on record. Note that global warming varies across landmasses and water basins and is more significant overland due to the thermal inertia of the oceans. Rising global temperatures are challenging ecosystems and economies and putting ecological integrity and resilience at risk (GISTEMP Team, 2019, Hansen et al., 2010).
- **Oceans are changing, and habitats are shifting:** The ocean temperature has increased significantly since 1969, particularly in the top 700 meters. Additionally, increased global temperatures cause oxygen levels and nutrients in the oceans to decrease. Analyses of direct measurements at sites show that zones with minimum oxygen levels have increased by several million square kilometers during the past 50 years (Breitburg et al., 2018). These changes are challenging numerous species and habitats, such as the Adelie penguins in Antarctica (Clucas et al., 2014), as well as coral reefs worldwide.
- **Sea levels are rising**: The sea level is rising each year, with a record high in 2017 (Blunden, Arndt & Hartfield, 2017). Global sea levels are rising with approximately 0.3 cm each year and are expected to rise between 25.4 cm and 81.28 cm by the end of the century, putting numerous countries such as the Maldives at risk. To be more precise, satellite altimetry estimates that global sea levels have been increasing at a rate of ~3 ± 0.4 mm per year since 1993. Research shows this rate is accelerating, and global sea levels may reach up to 65 cm by 2100 (Nerem et al., 2018).
- **Ocean acidification is increasing**: The acidity of the ocean waters has increased by 30% and the amount of carbon dioxide absorbed by 2 billion tons per year. Acidification affects coral skeletons, which are also prone to coral bleaching and extinction. Research shows that lower pH leads to a decline of 52-73% in the larval settlement on reefs.
- **Corals are disappearing:** In fact, coral bleaching is one of the clearest evidence that global warming is affecting species worldwide. A study showed that after the marine heat wave in 2016, the corals on the Great Barrier Reef started to accumulate excessive heat and suffered a tremendous die-off (Hughes et al., 2018).
- **Ice sheets are melting:** The ice sheets are melting at a high rate, contributing to sea-level rise. According to NASA's Gravity Recovery and Climate Experiment, between 1993 and 2016, Antarctica has lost

more than 127 billion tons of ice per year, while Greenland more than 286 billion tons per year. Consequently, sea level rise rates have tripled over the last ten years due to the melting of the Antarctic ice (IMBIE, 2018).

- **Glaciers are disappearing**: Glaciers – which contain ¾ of the world's freshwater – are retreating worldwide, including in the Alps and the Himalayas. In Montana's Glacier National Park, for instance, the number of glaciers has declined from 150 to 25. In addition, data provided by the U.S. Geological Survey and Portland State University shows that a large number of glaciers have shrunk since 1966.
- **Snow and permafrost are melting:** Snow is melting earlier, and spring snow has decreased over the past 50 years, particularly in the Northern Hemisphere. As the winter season shortens, whole regions are exposed at risk. In Yamal, Russia, for instance, as the permafrost started to melt in 2013, warm temperatures brought rain which then froze, leaving thousands of animals to starve. Sea ice is also melting earlier, which can be detrimental. A study showed that the earlier melting of Arctic sea ice in spring might leave polar bears to starve (Pagano et al., 2018).
- **Extreme weather events and pandemics are a fact**: The number of extreme weather events, such as flooding and heat waves, is increasing worldwide. As stated earlier, record high-temperature events have increased in the US. To provide an example, in 2015, drought in California led to the worst water shortage in 1,200 years (Marvel et al., 2019). Evidence also shows that the numbers of North Atlantic hurricanes and storms that reach categories 4 and 5 have increased dramatically since the 1980s. In addition, scientific research shows that the speed of tropical storms has slowed by 10% over the last 70 years, which results in more time to unleash rainfall (Kossin, 2018).

The Effects of Global Warming Across the Globe | 0.5°C Matters

Climate change can lead to drastic changes, and even a half-a-degree change can result in adverse ecological, health, and financial outcomes. As global warming rise might reach 2°C, scientists warn that global warming should be kept at 1.5°C above preindustrial era levels.

- **Sea-level rise and coral bleaching**: If global warming is maintained at 1.5°C, 46 million people will be affected by a sea-level rise of 48 cm. If global warming rise reaches 2°C, however, 49 million people will be

affected by a sea-level rise of 56 cm by 2100. Marine biodiversity is also at a higher risk at 2°C compared to 1.5°C. Coral reefs, for instance, will be lost by 2100 if warming reaches 2°C. As explained above, coral bleaching is a fact and has become five times more common globally (Hughes et al., 2018).

- **Arctic ice levels and winter seasons**: Satellite data shows that Arctic ice levels are decreasing. If the global temperature rise reaches 2°C, an ice-free Arctic summer could happen once every 10 years, compared to once every 100 years at 1.5°C. Snow is also melting earlier. Scientists predict that people will have to climb up to the 10,000-foot mark to see snow on mountains, which will affect habitats and the winter tourism economy. Moreover, climate change will challenge species. If global warming continues to rise, researchers predict that 70% of king penguins can disappear as their hunting and breeding spots will become insufficient (Crisofari et al., 2018).
- **Extreme weather events and detrimental air quality**: If we reach the global temperature rise of 2°C, researchers predict a 170% increase in flood risk. A rise of 2°C will lead to low water availability with more than 410 million residents exposed to severe drought by 2100, compared to 350 million people at a rise of 1.5°C. In fact, if warming reaches 2°C, 28% of the world's population will be exposed to extreme heat waves at least once every 20 years, compared to 9% if warming is maintained at 1.5°C.
- **Wildlife and food production**: Climate change affects the whole planet. If global warming is maintained at 1.5°C, 6% of insects, 8% of plants, and 4% of vertebrates will be affected. In comparison, if warming reaches 2°C, 18% of insects, 16% of plants, and 8% of vertebrates will be affected to the point of extinction. NASA reports that the Amazon will disappear if dry seasons last for more than five-seven months. In addition, baobabs which contain more than 500 cubic meters of wood and live for more than 2,000 years are also at risk; a study showed that nine of the 13 oldest and five of the six biggest African baobab trees have died (Patrut et al., 2018). Half-degree warming will affect food production and economic growth. To provide an example, beer supply can also decline due to the effect of climate change on barley yields (Xie et al., 2018). Via a process-based crop model and a global economic model, researchers found that heat and drought can lead to yield losses from 3% to 17% which can also lead to a drastic increase in prices (e.g., +193% in Ireland). Although the beer supply is not the most concerning aspect of global warming, data shows that climate change has a detrimental impact on production costs. Additionally, global warming will cause some species, such as mosquitoes, bark beetles, and ticks, to thrive devastating forests and crops.

- **Costs and health risks**: Although global warming is detrimental, climate change deniers refuse to admit that 0.5°C can make a difference. The truth is that since 1906, the surface temperature has risen by more than 0.9°C, which has already had a significant effect on economies. From agriculture to infrastructure, global warming has measurable financial impacts. Only in 2017, the Atlantic hurricane season cost the US more than $265 billion. After Hurricane Maria in Puerto Rico, analysts estimated a mortality rate of 14.3 deaths per 1,000 people between September 20 and December 31, 2017 (Kishore et al., 2018). According to a global report, by the end of the century, the US will spend more than $23 billion responding to wildfires. In fact, if global warming continues, the US economy will decline by 10%. The days of work missed and the number of doctor's appointments due to diseases, such as mosquito-borne malaria, will also have a detrimental effect on economies worldwide. Moreover, as a warmer climate means malaria, climate change will lead to various external and internal changes in humans. For instance, blood disorders such as sickle cell and thalassemia may arise as they have protective functions against malaria. (Fourth National Climate Assessment, Volume II, 2018).

Is Global Warming Manmade?

It's a well-known fact that climate changes are cyclic and the Earth's climate has fluctuated throughout history due to variations in the Earth's orbit. Scientists reveal there have been seven cycles of glacial advance and retreat; the last ice age ended 7,000 years ago marking the beginning of the modern climate era. Although climate change deniers claim that today's global warming is normal ice-age-recovery warming, research shows that global warming rose of 4°C to 7°C over 5,000 years. In contrast, in the 20th century alone, global warming has increased with 0.7°C – ten times faster than the normal ice-age-recovery warming rate. Since 1885 to 1945 global maps tend to appear warmer moving towards 1950. Data from 1880 to 2014 provided by the *National Aeronautics and Space Administration (*NASA), National Oceanic and Atmospheric Administration (NOAA), the Japan Meteorological Agency, and the Met Office Hadley Centre (United Kingdom), all show rapid warming over the last decades. Such rates are extremely unusual, and paleoclimate record shows that manmade causes of pollution have influenced climate change (Marvel et al., 2019). Models predict that the temperatures may rise between 2°C and 6°C, which can be fatal.

While some pollutants block the sun's rays and produce a cooling effect, scientists reveal that carbon dioxide and other greenhouse gases can trap sunlight and solar

radiation and cause the planet to get warmer, a process known as the greenhouse effect. The burning of fossil fuels and coal-burning power, for example, are the largest manmade sources of air pollution. Note that fossil fuel use increased significantly in the post-War era (with approximately 5% per year). In the US, the transportation sector is the second largest source of CO2 emissions (1.7 billion tons of CO2 emissions a year). Interestingly, tourism worldwide accounted for 8% of greenhouse gas emissions between 2009 and 2013 (Lenzen et al., 2018). Data shows that air pollution caused 8.8 million premature deaths globally. Apart from the greenhouse gas emissions globally, a wide range of human activities have a detrimental impact on the planet:

- Data shows that approximately ¾ of the land surface has been influenced by humans, and more than 75% of freshwater resources are used for agriculture. Moreover, land degradation has reduced land surface productivity by 23%, and people are exposed to risks of floods due to the significant loss of coastal habitats.
- Human actions have an impact on wildlife and migration, with 33% of marine species being harvested at unsustainable levels. More than 40% amphibian species, for example, are already threatened.
- Plastic pollution has increased ten times since 1980. Additionally, data shows that 300-400 million tons of heavy metals, solvents, and other wastes are discarded into the world's waters.

Can We Stop Global Warming?

Global warming is happening and scientific evidence shows that humans play a crucial role in climate change. In 2014, the US was the second-largest emitter of pollutants (15%) after China (25%). In order to maintain global warming at 1.5°C, countries should decrease greenhouse emissions and turn to renewable energy sources, energy-efficient technology, and sustainability. Note that at the United Nations Conference on Climate Change in Paris, 195 countries agreed to meet Paris Agreement commitments with a goal of maintaining global warming at 1.5°C above preindustrial times. While policymakers worldwide must tackle land and sea use, direct exploitation of organisms, climate change, pollution, and invasive alien species, developing countries should receive support to adopt cleaner energy technologies that can benefit their economies.

Alarmingly, climate policy opponents insist that policymakers should ignore climate change warnings, claiming there's been a slowdown in global warming since 1988. Yet, scientists reveal that this controversial hiatus has never occurred and is based on erroneous data. Calculations reveal we have a 2.8 trillion metric tons carbon budget to keep global warming at 1.5°C. Nevertheless, 79% has already been

exhausted; only between 2008 and 2017, 398 billion metric tons have been used. As there are only 580 billion metric tons left, our carbon budget might finish in less than 15 years.

In fact, computer simulations show that if countries turn to carbon-free energy, around 1,000 gigatons of fossil carbon will have been released since the start of the Industrial Revolution and CO_2 concentrations will peak by 2200. In this scenario, temperatures will rise by 2-3°C, and the Earth will enter a cooling phase of 100,000 years. If countries do not respond to climate change, however, CO2 emissions will reach 5,000 gigatons, CO2 concentrations will jump to toxic levels of over 1900-2000 ppm, temperatures will increase to 6-9°C, and sea levels will rise by 70 meters until the Earth cools down and reaches today's levels – 500,000 years from now. If individuals and regulatory bodies do not take any actions to prevent a Hothouse Earth scenario, scientists predict that temperatures will increase above any interglacial period in the past 1.2 million years and sea levels will be higher than at any period in the Holocene era (Steffen et al., 2018) Interestingly, such hothouse has happened before; the Paleocene-Eocene Thermal Maximum (PETM) occurred 55 million years ago and was triggered by greenhouse gas emissions.

Does One Degree Matter?

Global warming, characterized by a drastic increase in the average temperature in the Earth's atmosphere, is happening right now. The current temperature rise of 1°C is eminent and encompasses extreme weather conditions, rising sea levels, melting glaciers, and shifting populations. A change of only 0.5°C can be fatal to the planet and condemn future generations to extreme weather and financial conditions. Note that a 1-2°C drop was enough to send the Earth to the Little Ice Age. Manmade climate changes raise numerous ethical questions about the future of our planet and humankind. If authorities fail to reduce manmade pollution emissions and keep global warming at 1.5°C, temperatures may increase above 2°C, which can be detrimental to people, wildlife, and nature.

Does global warming exist? Is it happening now? Is manmade pollution responsible for climate change? The facts simply speak for themselves. Manmade global warming has already reached a five-sigma level, which describes a minimal probability of 1 in 3.5 million that manmade climate change evidence would appear at random. Global warming is real, and individuals worldwide should start planting the seeds toward a better future.

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